APPRAISAL OF WATER QUALITY IN THE BOULDER RIVER DRAINAGE
AND
POTENTIAL METHODS OF POLLUTION ABATEMENT OR CONTROL

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Mines that are the most significant contributors to pollution in the Boulder River were examined in the field by SCS and Water Quality Bureau personnel on November 8, 1974. Abatement and corrective measures also were discussed. Water quality samples were collected on November 13, 1974, at 11 sites and were analyzed to determine water quality conditions in the area.

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I. INTRODUCTION

The effects of 100 years of mining activity in the Boulder River drainage near Boulder, Montana, has degraded severely water quality in portions of the watershed. Poor water quality has led to suppression of the fishery and associated aquatic community, particularly in the Boulder River and its tributaries between Basin and Boulder, Montana.

In October, 1974, the Soil Conservation Service (SCS) requested the Water Quality Bureau of the Montana Department of Health and Environmental Sciences to make the following evaluations:

1. Determine major pollution sources in the drainage and ascertain what can be done to achieve a positive effect on the fisheries of the Boulder River.

2. Determine if dilution water released from a proposed dam on the Little Boulder River will improve the Boulder River fishery.

The SCS provided partial funding for this study.

Purpose and Scope

The purpose of this report is to:

1. Identify and describe basic water quality and principal sources of pollution in the Boulder River and describe the concentration, volume, frequency, and duration of discharge of pollutants into the river.

2. Make an appraisal of measures that could be taken to correct or abate the pollution problem and make estimates of costs of such measures.

3. Recommend a program to obtain additional quantitative data on water quality in the drainage.

4. Provide all basic data available from the Water Quality Bureau that relates to the project.

Comet Tailings

Predominant pollution sources in the High Ore Creek drainage are acid mine seepage and erosion of tailings in the vicinity of the inactive Comet Mine (Figure 1). The three acid mine seeps at the Comet Mine originate within the tailings area. Two of the seeps join within the tailings area and were sampled as a single source before entering High Ore Creek at the toe of the tailings. The third seep was sampled separately at the toe of the tailings before entering High Ore Creek. All of the seeps probably are perennial. The major cause of tailings erosion is High Ore Creek. The stream has been rechanneled around the edge of the tailings, but the channel is small and appears to have insufficient gradient to prohibit freezing. When the channel freezes, High Ore Creek overflows into the tailings area, and many tons are eroded. Channel freeze-up last occurred in 1973, and emergency efforts by Jefferson County employees were required to remove ice from the channel so flow could be re-established.

The quantity of acid wastes and hence, toxic metals in solution and suspension, depends on the quality of water and quantity of oxidizable material (usually pyrites) with which the water comes in contact. In a small mine with large quantities of water, most of the acid produced and metals leached are flushed out as they are produced. Thus, if flows are increased, then the acid and metals produced are diluted but the total quantity produced probably changes little. Larger mines with highly variable flows may accumulate the acid and metals produced during low flow periods, flushing during periods of high flows. Acid levels and toxic metals concentrations in the discharge may, therefore, be quite variable (McArthur, 1970). Flows from acid mine seeps at the Comet Mine site appear to be quite uniform throughout the year.

Municipal and Industrial Discharges

Domestic wastewater from the town of Boulder and the state training school and hospital is treated by sewage lagoons before discharge to the Boulder River (MPDES Permit No. MT 0023060). The discharge from the lagoon system is unchlorinated, continuous, and varies from 0.03 cfs to 0.39 cfs. There are no other discharges from municipal sewage treatment facilities in the drainage. However, illicit discharges from private septic tanks in the town of Basin have been reported.

The Jib Mine in Basin has applied for a permit to discharge wastewater under the Montana Pollutant Discharge Elimination System (MPDES Permit No. MT 0023370). Specific flow, suspended solids, turbidity, and metals limitations will be specified in the permit, which was issued on November 30,

1974. The mine is not discharging at present; however, analyses of samples collected during periods of discharge are given in Appendix II.

Effects of toxic metals and sediment on fish have been studied extensively, but direct application of the literature may be inappropriate. It is not possible to duplicate natural stream conditions in laboratory. For example, the response of rainbow trout under conditions of stress cannot be representative of the diverse aquatic community present in streams (rainbow trout are the most commonly used salmonid in bioassay studies). Further, water chemistry varies widely from stream to stream, within reaches of a stream, and seasonally within a specific reach of a specific stream. So, published data should be used as a guide and not as a substitute for adequate study. Recommended limits for copper, lead, iron, arsenic, and lead are given in Table 2. Also shown are concentrations that may inhibit more sensitive forms of aquatic life, such as *Ephemeropetera* (mayflies), *Plecoperta* (stoneflies), and *Tricoptera* (caddisflies).

TABLE 2. RECOMMENDED LIMITS FOR SELECTED TOXIC ELEMENTS

Element	Recommended Limit for Fish - mg/l(1)	1/10 acute levels(2)
Arsenic	1.0	0.1
Copper	0.02	0.001
Lead	0.1	0.01
Iron	none specified	0.02
Zinc	0.1 - 1.0 (reported lethal for soft water)	

(1) McKee and Wolf (1963)
(2) Horpestad (1974)

WATER QUALITY

The Boulder River is a low dissolved solids, soft to moderately hard, calcium-bicarbonate type water with moderate sulfate concentrations. Toxic metals concentrations from acid mine seeps in the Boulder Batholith region is causing severe pollution of the Boulder River and some of its tributaries (Table 3). Consequently, the Boulder River between Basin, Montana, and the USGS station near Boulder, Montana (Table 1), High Ore Creek and Cataract Creek do not meet water quality standards(1) for $B\text{-}D_1$ streams.

The quality of water in the Boulder River is considered good down to Basin. At Basin, mine tailings and perhaps metals input from Basin Creek appear to degrade the quality. Further downstream, metal-bearing wastes and sediment from Cataract and High Ore Creeks significantly degrade the stream. Degradation of the Boulder River from these sources is apparent downstream to at least the confluence with Muskrat Creek. Below Muskrat Creek, the Boulder River appears to be a high quality stream based on the presence of sensitive aquatic life forms; however, relatively high metals concentrations persist downstream to the Jefferson River (Table 3).

There have been no comprehensive sampling programs conducted on the Boulder, and available data are insufficient to calculate loads and seasonal and diurnal changes in loads of toxic metals and sediment. Further, the impact of dissolved toxic metals is difficult to separate from the effects of sediment. Both toxic metals and sediment are subject to wide variations in concentrations and loading. Changes in flow with season and precipitation greatly influence metal concentrations. Also, both sediment and metals are precipitated in the stream bottom and can be resuspended as flows increase. From Boulder River samples collected downstream of Boulder, toxic metals concentrations appear to increase with flow while toxic metals loads increase substantially with increased flows (Table 3).

The proposed dam will have no impact on water quality upstream from Boulder unless some project effort is directed toward abatement of upstream mine drainage problems. The least expensive and one of the most beneifical abatement measures would be rebuilding of the High Ore Creek bypass around the Comet Mine tailings. Other treatment and/or abatement

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(1) Montana Water Quality Standards.

TABLE 3. TOXIC METALS LEVELS IN THE BOULDER RIVER DRAINAGE

Station, Location and Date	Flow (cfs)	Concentration (mg/l)					Load (lbs/day)				
		Zn	Cu	Fe	As	TDS	Zn	Cu	Fe	As	TDS
Boulder River at Basin, Montana (6N, 5W, 18D)											
9/5/73	12.9*	<0.01	<0.01	0.10	<0.01	98	<0.70	<0.70	7.0	<0.70	6827
1/14/73	11.4	-	<0.01	0.12	<0.01	115	-	<0.61	7.4	<0.61	7066
11/13/74	13.5	0.01	0.01	0.20	<0.01	90	0.72	0.72	14.5	<72	6537
Boulder River above Cataract Creek (6N, 5W, 16C)											
11/13/74	18*	0.12	0.02	0.24	<0.01	89	11.6	1.9	23.2	<0.9	8619
Crystal Mine (7N, 5W, 20B)	50 gpm*	4750	62	218	12	-	2850	37	131	7.2	-
Cataract Creek above Big Limber Gl. (6N, 5W, 9C)											
9/15/72	3.42	0.10	0.04	-	<0.01	119	1.8	0.74	-	<0.18	2194
11/13/74	6.7	0.96	0.07	0.15	0.01	-	34.7	2.5	5.4	0.4	-
Boulder River above High Ore Creek (6N, 5W, 22AA)											
4/10/73	35*	0.03	<0.01	0.34	-	92	5.6	<1.9	64.0	-	17,324
11/13/74	25.4	0.24	0.03	0.28	<0.01	92	32.8	4.1	38.2	<1.37	12,572

*Estimated

Station, Location and Date	Flow (cfs)	Concentration (mg/l) Zn	Cu	Fe	As	TDS	Load (lbs/day Zn	Cu	Fe	As	TDS
Minor seep, Comet tailings (7N, 5W, 36C)											
6/5/73	3 gpm*	18	0.01	10	0.34	443	0.65	0.0004	0.36	0.01	1.59
11/13/74	5 gpm*	17	0.02	28	1.9	702	1.0	0.001	1.7	0.11	40.2
Major seep from Comet tailings (7N, 5W, 36C)											
6/5/73	10 gpm*	36	<0.01	-	0.22	1005	4.3	<0.001	-	0.03	121
11/13/74	20 gpm*	43	0.02	19	3.7	969	10.3	0.005	4.6	0.89	233
High Ore Creek above Comet Mine (7N, 5W, 36D)											
11/13/74	0.4 cfs	0.01	0.01	0.60	<0.01	105	0.02	0.02	1.30	<0.02	2.26
High Ore Creek 1/4 mile below Comet tailings (6N, 5W, 2A)											
11/13/74	1.0 cfs	6.1	0.02	3.3	3.7	233	32.8	0.12	17.7	19.9	1254
Boulder River at USGS Station (5N, 4W, 3CAD)											
4/17/73	115	0.23	0.01	1.2	<0.01	-	143	6.2	744	6.2	-
4/13/73	64	0.70	0.07	5.8	<0.01	-	241	24.1	2000	3.4	-
5/10/73	136	0.82	0.13	0.48	<0.01	92	601	95	352	7.3	67,440
3/8/73	22*	0.28	0.03	0.52	<0.01	149	33.1	3.6	61.5	<1.2	17,636
2/21/73	19	1.3	0.10	-	0.02	157	133	10.2	-	2.0	16,078
1/4/73	19*	0.42	0.02	-	0.26	159	42.9	2.0	-	26.6	16,253
11/13/74	49*	0.26	0.01	0.20	0.02	90	68.5	2.6	52.7	5.3	23,725

*Estimated

Station, Location and Date	Flow (cfs)	Concentration (mg/l) Zn	Cu	Fe	As	TDS	Load (lbs/day) Zn	Cu	Fe	As	TDS
Boulder River at Elkhorn, Montana road bridge (5N, 3W, 19BAC)											
4/13/73	75*	0.43	0.06	2.2	0.02	-	173	24.2	888	8.07	-
11/13/73	52.2	0.26	0.01	0.23	0.02	118	73.0	2.8	64.6	5.6	33,139
Boulder River at U. S. Highway 10 (1N, 3W, 2BAC)											
9/22/72	-	0.02	0.02	-	0.01	330					
10/5/72	-	0.10	0.01	-	0.01	301					
1/4/73	-	0.07	0.01	-	0.23	306					
2/21/73	-	0.28	0.05	-	0.01	274					
3/29/73	-	0.06	0.02	0.15	<0.01	245					
5/10/73	70	0.56	0.16	0.67	<0.01	160	211	60	253	<3.8	60,370
8/25/72	31.3	0.04	0.02	0.12	0.01	276	6.7	3.4	20.2	1.7	46,477

techniques are difficult to evaluate due to lack of data concerning the problem (Table 3).

Downstream from the proposed dam, maintenance flows and sub-surface return flows from irrigated lands will provide diluation for polluants (toxic metals) in the river. This may improve the aquatic environment. The magnitude of this improvement, however, cannot be estimated due to the poor state of knowledge of river chemistry and the effects of the quality on aquatic life.

VI. BIOLOGICAL OBSERVATIONS AND IMPACTS

The following observations were made by R. D. Braico, Public Health Engineer, in August, 1972 to October, 1974. Although Mr. Braico is not a professional aquatic pollution biologist, his background and aquatic experience make these observations a meaningful assessment of stream conditions. Additional qualitative and quantitative aquatic data and examination by an experienced professional biologist is needed to further document stream conditions.

Boulder River above Basin (from Basin to Bernice)

Appeared to support good trout and insect population (may-flies observed hatching and several fish raising in runs). Trout in this section are small, probably due to habitat constraints. Many of the historic meanders in the section were removed to facilitate railroad construction. So, the Boulder River in this section can be characterized as mostly fast-moving with few pools. Good aquatic plant growth also is apparent in this section.

Boulder River at Basin

Stream begins to change, apparently from input of sediment from old Jib tailings area. Suppression of plant growth is readily apparent. A sculpin (Cottus) was observed at the Kleinsmith Road Bridge (just above the main Jib tailings area) on November 13, 1974. The Sculpin is considered an excellent indicator of high water quality.

Basin Creek

Some trout were observed about four miles above the mouth; however, stream receives substantial input of metals from Bullion Mine via Jack Creek.

Cataract Creek

Some trout have been observed in the headwaters region above the Eva Mae Mine. Cataract Creek below its confluence with Uncle Sam Gulch has no fish or aquatic insects (six obser-vations between July, 1972 and November, 1972). Rocks in this stream segment area are iron stained.

No fish or aquatic insects apparent in Uncle Sam Gulch Creek during several inspections between July, 1972 and November, 1974.

Large quantities of sediments have been deposited on the stream bottom of Uncle Sam Gulch Creek downstream of the Crystal Mine.

Boulder River at Confluence with Buttermilk Jim Gulch

No fish observed; no aquatic insects observed hatching in evening (July, 1972), and no aquatic insects on stream rocks. Plants and algae attached to rocks were choked with fine sediment (apparently mill tailings).

Hire Ore Creek

The streambed is choked with tailings from the Comet Mine; no fish or aquatic insects have been observed in several trips.

Boulder River at USGS Station Below Confluence with Muskrat Creek

No fish observed, but Al Wipperman (Fish and Game Department), and Mr. Braico observed viable population of mayflies and stoneflies in April, 1973 (most likely caddisflies too). Plants and algae attached to rocks; looks good again (similar to that noted above Basin).

Boulder River at Elkhorn Road Bridge

Two sculpin were observed while gaging on November 13, 1974.

II. ABATEMENT OR CONTROL OF POLLUTION SOURCES

All sources of pollution can be abated or eliminated. The cost, however, may be prohibitive and not commensurate with benefits. This commonly is the case with mine drainage. Problems on the Boulder River, potential solutions, and costs are summarized below.

	Location	Problem and Potential Treatment Measures
1.	Crystal Mine	Extremely toxic effluent 1. Plug tunnel - owner objection, technically difficult 2. Lime neutralization - very expensive (not well understood)
2.	Comet Tailings	Erosion - serious sediment problem 1. Stream diversion - $10,000 to $25,000 2. Regrade and cover - very expensive 3. Sediment trap (dam) - very expensive Seepage - toxic metals 1. Lime neutralization - very expensive 2. Diversion of all waters - effects technically not predictable with present knowledge of area
3.	Jib Tailings	Sediment and possibly toxic metal seepage 1. Reroute stream and riprap tailings - not sufficiently understood; expensive 2. Intercept groundwater - not understood at present 3. Lime neutralization - not understood at present
4.	Boulder River between Basin and Boulder	Poor quality due to toxic metals 1. Remove pollutants via one through three above - see above 2. Dilute wastes with dam releases - problem not well enough understood to estimate costs.

The problems and potential solutions and costs above are self-explanatory. Several alternatives are worth additional

comment. Acid mine seeps from the Comet tailings are not strongly acid and additional tests should be conducted to determine if this waste can be treated economically. Characteristics of the seeps have not been established sufficiently to estimate treatment costs.

Erosion of the Comet tailings due to ice in the diversion channel causes enormous quantities of metal-bearing sediment to enter the Boulder River. An adequate diversion channel around the tailings would not be unreasonable in cost. Flow data are too scanty to make a good engineering cost estimate. An appraisal of the cost can be made assuming a channel with a four-foot bottom width, an average of six feet deep, 2 : 1 side slopes, dirt work at $1 per cubic yard, and 1,500-foot length. A hydraulic drop structure also would be needed. A rough estimate of cost would be $10,000 to $25,000. Such a channel would greatly decrease erosion of old tailings.

Another alternative for stream water quality improvement in the Boulder River below Boulder is release of water from the proposed dam. The river system is not well enough understood at present to predict the impact of dam storage or releases on downstream water quality. Additionally, the benefits from reduction of metals concentrations are not well understood. Water quality enhancement by water release is a viable alternative and warrants additional examination.

III. PROGRAM FOR ADDITIONAL INVESTIGATION

Data presented in this report are taken from other investigations, particularly the Water Quality Bureau Water Quality Management Plan for the Upper Missouri River drainage. These data are fragmentary and cannot be used to accurately determine pollution loads and impacts in the Boulder River. To more accurately determine the nature of pollution in the Boulder River, the following program is recommended. The program should have a duration of at least two years.

Pollution Source Monitoring

Effluent from major pollution sources--the Crystal Mine effluent and three seeps at the Comet tailings--should be monitored periodically. During the fall and winter low flow period, bimonthly samples would be sufficient. During the spring runoff, semi-monthly or weekly samples would be desirable. Monthly samples would be sufficient for the remainder of the year. Parameters that should be measured are:

Stream flow
Temperature
Turbidity
pH
Specific conductance
Acidity or alkalinity
Total suspended solids
Dissolved and total recoverable or total metals, including arsenic, lead, copper, zinc, iron, cadmium and manganese

A more complete analysis should be made on each source annually. This would include the above list plus major cations and anions. Results of the first year's sampling may indicate some constituents should be added or deleted.

Stream Quality Monitoring

The influence of pollution from mines on natural water quality can be assessed by monitoring at the following stations:

1. Boulder River above Basin

2. Basin Creek at the mouth

3. Boulder River above Cataract Creek

4. Cataract Creek at mouth

5. Boulder River above High Ore Creek

6. High Ore Creek at the mouth

7. Boulder River at Boulder

8. Boulder River at Elkhorn Road Bridge

These stations should be measured bimonthly during the low flow period (October through March), seim-monthly or weekly during spring runoff, and monthly to October. Parameters should be those outlined in pollution source monitoring.

Biological Surveys

Determinations of extent of stream pollution by field examination of streams. This would involve qualitative and quantitative sampling of aquatic biota, particularly invertebrates. In addition, periphyton surveys should be made to distinguish dissolved metals toxicity and sediment related problems.

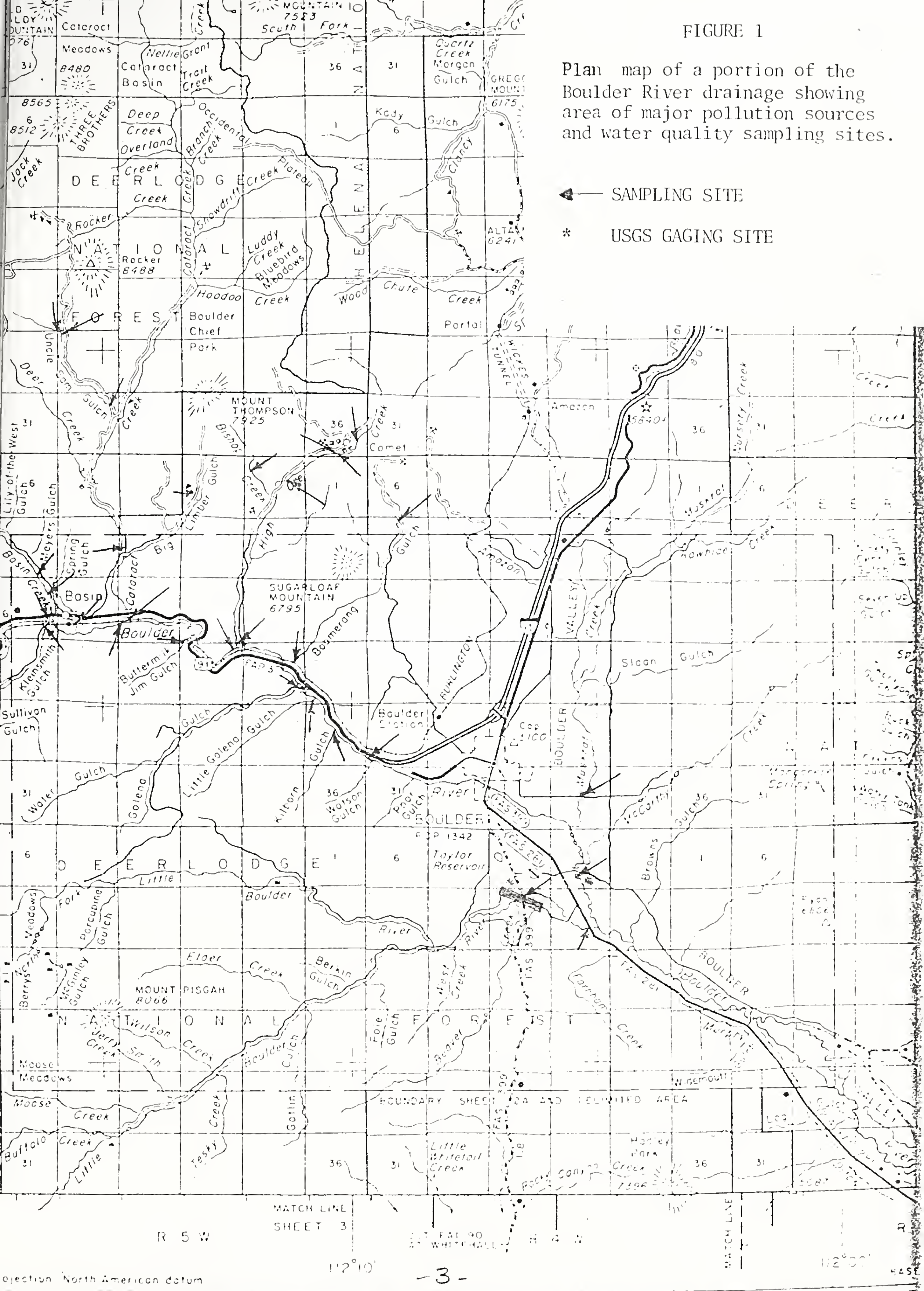
This program would define the quantitative impacts of mine wastes on the Boulder River and would document the quality of water from the Comet tailings and the Crystal Mine. Wastes tributary to the Boulder River at Basin should be examined in more detail. The river is biologically suppressed below Basin, but the reasons for this suppression are not clear. Additional physical examination of the area and water quality and biological testing would be valuable.

FIGURE 1

Plan map of a portion of the Boulder River drainage showing area of major pollution sources and water quality sampling sites.

SAMPLING SITE

* USGS GAGING SITE



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BOULDER RIVER DRAINAGE WATER QUALITY SAMPLES

Collected November 13, 1974

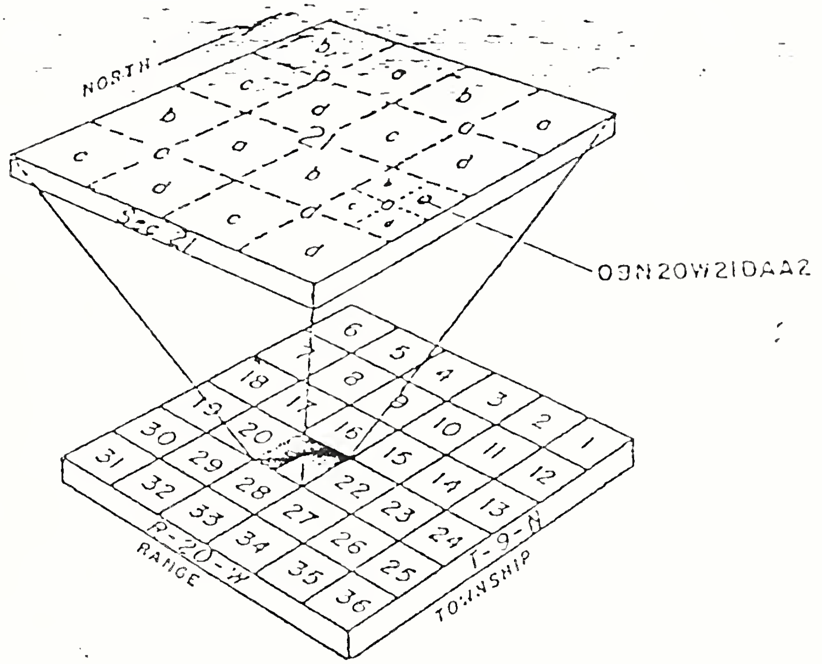
APPENDIX II

BOULDER RIVER DRAINAGE WATER QUALITY DATA

APPENDIX I

SYSTEM FOR GEOGRAPHIC LOCATION OF FEATURES

Wells, springs, water-sampling locations, and stream-gaging locations are assigned numbers based on the system of land subdivision used by the U. S. Bureau of Land Management. The number consists of twelve characters and describes the location by township, range, section, and position within the section. The figure below illustrates the numbering method. The first three characters of the number give the township, the next three characters the range. The next two numbers give the section number within the township, and the next three letters describe the location within the quarter section (160-acre tract) and the quarter-quarter section (40-acre tract), and the quarter-quarter-quarter section (10-acre tract). These subdivisions of the 640-acre section are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quadrant. If there is more than one feature in a 10-acre tract, consecutive digits beginning with 2 are added to the number. For example, if a water-quality sample was collected in sec.21,T.9N.,R20W, it would be numbered 09N20W21DAA2. The letters DAA indicate that the well is in the NE¼ of the NE¼ of the SE¼, and the number 2 following the letters DAA indicates there is more than one water-quality sampling location in this 10-acre tract.



II. SUMMARY AND CONCLUSIONS

The Boulder River above Boulder, Montana, is severely affected by drainage from mining operations. Both toxic metals and metal-bearing sediment enter the Boulder River and some of its tributaries near Basin. Metals and sediment significantly degrade water quality and inhibit stream aquatic life. Principal pollution sources are the Crystal Mine and Comet Mine tailings near Basin, Montana.

Previous investigations by the Water Quality Bureau have provided considerable basic data documenting water quality conditions in the Basin area and indicate concentration of metals may increase during peak flows and loads greatly increase. Sediment concentration generally increases with increasing stream flow and is greatly influenced by erosion of the Comet tailings. Basic water quality in the Boulder river above Basin is excellent.

The proposed dam will not affect water quality in the Boulder River upstream from Boulder but will influence concentrations of metals and sediment downstream from the dam. Water released from the dam may improve the aquatic environment downstream, but the magnitude of this improvement cannot be estimated.

Problems and potential abatement methods for pollution sources are described in this report. If the Little Boulder River Dam project can include some water pollution abatement measures, there can be a significant improvement in water quality in the river.

III. SURFACE WATER RESOURCES

Headwaters of the Boulder River drain the Boulder Batholith, a mineralized mountain area between Butte and Boulder, Montana. From Boulder, Montana, to its confluence with the Jefferson River near Cardwell, Montana, the Boulder River drains a broad agricultural valley. Large withdrawals from the Boulder River are made to irrigate land along this downstream segment. The U. S. Geological Survey has had several stream flow gaging stations in the Boulder River drainage (Table 1). None of these remain active.

Stream flows in the Boulder River and its tributaries are affected by local weather conditions, geology, and irrigation. March through early July is the most common snowmelt period and hence, period of peak flows; however, warm weather in mid-winter can produce significant short-term increases in stream flows. Spring runoff is a function of air temperature and precipitation and may be quite variable in both time and volume of runoff.

TABLE 1. SUMMARY OF U. S. GEOLOGICAL SURVEY STREAM FLOW GAGING STATION DATA (Partial Record Stations not Included)(1)

Station Name	USGS Station No.	Location(2)	Minimum Stream Flow (cfs) Instantaneous	Daily	7-day, 10-year low flow (cfs)	Average Annual Flow (cfs)	Period of Record
Boulder River near Boulder, Montana	0603300	5N4W3CA	0	0	5.0	121	1929-1932, 1934-1972
Boulder River	305	6N7W20C	not determined	0.5	not determined	11.7	1946-1953
Boulder River at Basin, Montana	43	6N5W18D	7.6	----------- not determined ---------			1921-1923
Boulder River near Basin, Montana	44	6N5W17	0.6	----------- not determined ---------			1919-1920
Muskrat Creek near Boulder, Montana	45	6N3W6B	0.8	----------- not determined ---------			1912-1914
North Fork Little Boulder River near Boulder, Montana	47	5N4W8C	---------------------- not determined ----------------				1924-1927

(1) USGS Water Resources Data for Montana.
(2) See Appendix I.

IV. POLLUTION SOURCES

Toxic metals discharged from mine seeps upstream of Boulder, Montana, are present in the Boulder River in concentrations reported to cause avoidance reactions to migrating fish, thus blocking existing or potential spawning runs. Fish food production, fish growth, and spawning success are inhibited severely in some tributaries and in portions of the Boulder River (Montana Department of Fish and Game, March 1, 1972). In addition to toxic metals from acid mine drainage, sediment from overburden, tailings and exposed cut slopes also is a problem. Much of the sediment eroded from tailings areas is known to contain high concentrations of toxic elements, such as lead, copper, cadmium, zinc, and arsenic. However, effects on aquatic life of toxic elements contained in sediment are not well known. Most research efforts have been directed towards the effects of toxic substances in solution.

Major water quality impairment of the Boulder River drainage occurs between Basin and Boulder, Montana (Figure 1). Impairment is due principally to input of sediment and toxic metals from sources in the High Ore and Cataract Creek drainages. In addition, substantial amounts of mill tailings have been eroded from the Jib Mine at Basin, Montana. Mining activity in other portions of the Boulder River drainage, such as Elkhorn and upstream of Basin, has resulted in several less significant problem areas. History and development of mining in the Boulder River drainage has been discussed by Roby, et. al. (1960).

Crystal Mine

Predominant pollution sources in the Cataract Creek drainage are acid mine seepage and sediment from the Crystal Mine at the head of Uncle Sam Gulch (Figure 1). Substantial sediment also is known to be eroded by precipitation from exposed banks near the mouth of Cataract Creek. Analyses of samples collected in the Cataract Creek drainage are discussed in Section V and given in Appendix II. Sediment problems at the Crystal Mine are attributable to lack of regard for control of water at the existing open pit operation. State mining and water pollution control laws should be adequate to correct this problem. Perennial acid mine drainage at the Crystal Mine is from inactive underground workings and is reported to be quite uniform. Since underground operations are expected to be restarted, state mining and water pollution control laws probably will be applicable.